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Acceptability of Water, Selected Beverages and Foods as a Function of Serving Temperature

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ABSTRACT

In Experiment 1 the consumer acceptability of water, four fruit-flavored beverages and tea was examined at five serving temperatures (38°, 52°, 74°, 97° and 120°F). Results showed significant main effects of beverage and temperature on acceptability ratings and a significant beverage x temperature interaction. Pure water, which was moderately acceptable at low serving temperatures, was the most unacceptable of all samples at high temperatures. In Experiment 2 the acceptability of three beverages and ten solid foods was examined at five serving temperatures (40°, 55°, 70°, 100° and 135°F). Results showed that the acceptability of each food item was greatest in the temperature range at which the food is normally served; except for foods normally served at ambient temperatures. The importance of temperature/acceptability functions for food and beverage selection under conditions where heating and/or cooling is not feasible, and the relationship of the present data to data on temperature/intensity functions in taste were discussed.

INTRODUCTION

STUDIES of the dependence of taste function on stimulus temperature have focussed on the examination of the effect of variations in solution temperature on the perceived taste intensity or taste thresholds of model tastants (see Pangborn et al., 1970; McBurney et al., 1973; Moskowitz, 1973, for a review of the early literature and examples of more recent studies). In contrast, there have been relatively few studies examining the effect of serving temperature on either the consumption or perceived acceptability of real foods and beverages.

Two early and notable exceptions were the investigations of Blaker et al., (1961) and Thompson and Johnson (1963), in which the effect of serving temperatures on the acceptability of vegetables, potatoes and meat was assessed. In these studies temperature was not systematically varied, but was allowed to vary within normal serving limits. Blaker et al. (1961) identified a range of acceptable temperatures for hot entrees and hot beverages of 130–170°F and for vegetables and potatoes of 140–165°F. Thompson and Johnson (1963) identified an acceptable range for meats of 150–160°F and for vegetables and potatoes of 160–170°F.

The above studies examined acceptability within the narrow range of likely serving temperatures for these foods. No studies have examined the acceptability of foods over a broad range of temperatures. This is most likely a result of the fact that proper food safety procedures require that the holding and serving temperatures for foods be maintained below or above a temperature range of 50–120°F. However, under certain extreme conditions, control over serving temperature may be minimal or absent. Also, the cost of heating and/or cooling foods and beverages may be so prohibitive under certain circumstances, as to only justify temperatures that render the items sufficiently palatable to consume. Under these conditions, knowledge of temperature-acceptability functions becomes important. As an example, Adolph (1947) performed some of the first practical experiments examining the effect of fluid temperature on the acceptability of water and flavored drinks in arid environments. In these studies (Adolph, 1947), men in water deficit were given a choice between warm (84°F) or cool (55°F) water. Significantly less water was consumed by the group given the warm water. In addition, when grape, lemon and orange flavorants were added to the water, none of the beverages was found to be more acceptable than pure, cool water.

Although the problem of fluid consumption in temperate climates is not as critical as in arid environments, information on the interaction between temperature, flavor, and acceptability are important for guiding choices among foods and beverages under conditions such as occur during hiking or camping, or in military field situations, Civil Defense operations, etc. Data on temperature-acceptability functions may also increase our understanding of the learned relationships between food temperature and acceptability and highlight the importance of the interaction between taste and temperature receptor mechanisms.

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EXPERIMENT 1

THE FIRST EXPERIMENT examined the temperature-acceptability functions for a variety of flavored beverages that are normally served cold and compared these functions to the temperature-acceptability function for pure water.

Materials & Methods

Five beverages and distilled water served as test stimuli. The five beverages were commercial orange, cherry, grape and lemon-lime drinks (Kool-Aid brand, General Foods), as well as instant iced tea with added sugar and lemon (Nestea brand, Nestle Co.) All beverages were prepared according to the manufacturer's recommendations. The four fruit-flavored beverages were prepared with the same amounts of added sucrose. All were mixed with distilled water, held overnight in sealed glass containers, then brought to one of five serving temperatures by placement of the glass containers in either a temperature controlled water bath or a refrigerator. The serving temperatures tested were 38°, 52°, 74°, 97° and 120°F (3.3°, 11.1°, 23.3°, 36.1° and 48.9°C).

All tests were carried out in standard light-, sound-, and temperature-controlled sensory booths. Five groups of 36 subjects were drawn from a pool of laboratory employees who had volunteered to participate in consumer tests. Each group of subjects evaluated each of the six samples (five beverages and distilled water) at one of the five serving temperatures. A labeled 9-point hedonic scale was used to assess acceptability.

Samples were presented randomly to each subject and were poured from their containers within 15 sec of testing. All subjects were given instructions to taste the samples immediately upon receipt to avoid moderation of the temperature. The holding temperatures of all samples were monitored throughout the experiment and remained within ± 2°F of the designated temperature. An interstimulus interval of 90 sec was maintained.

Results

Fig. 1 shows a plot of the mean acceptability ratings as a function of serving temperature for each beverage and distilled water. While almost all samples show a decline in acceptability with increasing temperature (distilled water and the lemon-lime drink show a peak at 52°F), the distilled water sample shows the most rapid decline in acceptability of all tested samples.

Analysis of variance conducted on the data showed significant ($p < 0.01$) main effects of temperature ($F = 7.75$; df = 4, 175) and beverage ($F = 24.06$; df = 5, 875), as well as a significant ($p < 0.01$) temperature x beverage interaction ($F = 2.43$; df = 20, 875). Table 1 shows the results of Duncan Multiple Range Tests ($p < 0.05$) of the mean ratings between samples at each temperature. Examination of the mean values shows the orange beverage and the instant iced tea to have the lowest acceptability ratings at 38°, 52° and 74°F. The cherry, grape and lemon-lime beverage and distilled water have higher ratings at these temperatures, with few significant differences among them. However, at the higher temperatures (97° and 120°F), the distilled water sample is least acceptable, and the cherry, lemon-lime and grape beverages, in that order, are rated maximally acceptable.

Discussion

The results show significant effects of both serving temperature and beverage flavor on the acceptability of beverages. In addition, there is a significant temperature x beverage interaction, due primarily to a more rapid decline in the acceptability of pure water with increasing serving temperature. Pure water, although rated as equally acceptable to the various fruit-flavored beverages at low temperatures, was rated least acceptable at very high temperatures. This suggests that, at high temperatures, the addition of any one of a variety of beverage flavoring agents will increase the acceptability of pure water.

In Adolph's (1947) studies, pure water served at 55°F was found to be more acceptable, in terms of amounts consumed, than water with 0.1% salt added, or than water served at 82°F. He also observed that at an ambient temperature of 98°F, pure water was preferred over an orange flavored drink; but that at temperatures above ambient (serving temperature not specified, ambient = 99°F), a grape flavored beverage was more acceptable than pure water. These data are consistent with the present data, showing that pure water is as (or more) acceptable than flavored beverages at below ambient serving temperatures, but that at above ambient temperatures, flavor additives increase the acceptability of water.

The implications of the above data are varied. Of the beverages tested, it is clear that a cherry-flavored drink is maximally acceptable, independent of temperature. Orange-flavored drink and instant iced tea are the least acceptable of the flavored drinks across all temperatures. It can be suggested then, that when cooling equipment is not available, a cherry-flavored drink will provide a maximally acceptable beverage, regardless of serving temperature. The relatively greater decrease in acceptability of pure water with increasing temperature, suggests that adding certain flavor additives to water can improve its acceptability when temperatures reach the 97°F range. Thus, these data may have implications for choosing beverages to use in certain civilian or military field situations.

Of interest, as fas as temperature-acceptability functions are concerned, is the fact that these data show near monotonic decreases in acceptability with increasing serving temperature for beverages that are normally served cold. A common sense notion would also predict that the acceptability of beverages (or foods) that are normally served *hot* would *increase* with increasing temperature, and that beverages or foods normally served at ambient temperatures would exhibit peak acceptability at ambient temperatures.

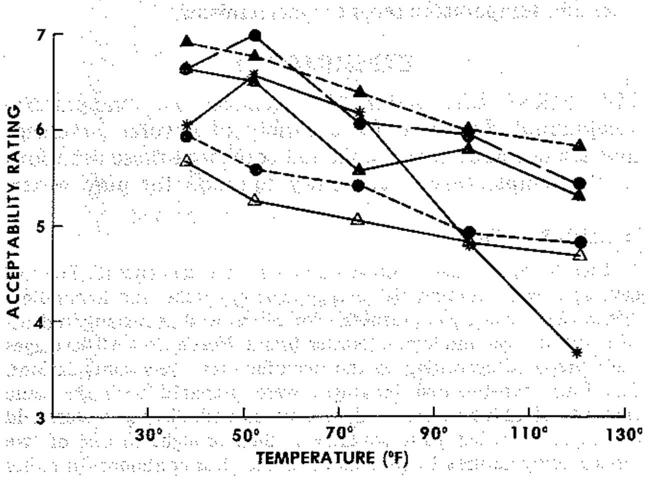


*Fig. 1—Mean acceptability ratings as a function of serving temperature for the five beverages and distilled water of Experiment 1: *——* Distilled water; ●------● Orange Kool-Aid; ▲——▲ Grape Kool-Aid; △——△ Tea w/sugar & lemon; ▲-----▲ Cherry Kool-Aid; ●———● Lemon-Lime Kool-Aid.*

EXPERIMENT 2

This study is an expanded report of data collected from our laboratory on the effects of serving temperature on the acceptability of 13 foods and beverages. These data have been abstracted in an internal report (Waterman and Westerling, 1974), but have not been previously reported in detail.

Materials & Methods

The 13 beverages and foods used in these tests consisted of a commercial lemonade drink, homogenized milk, coffee, baked ham, beef stew, pork sausage, creamed corn, hashed brown potatoes, apple pie, scrambled eggs, green beans, meatloaf and dinner biscuits. Each beverage or food was prepared and cooked in its recommended

Table 1—Results of Duncan Multiple Range Tests ($p < 0.05$) on the differences in mean ratings among samples tested in Experiment 1 [Mean ratings with the same superscript (a,b,c,d) are not significantly different]

38°F		52°F		74°F		97°F		120°F	
Beverage	Mean Acceptability	Beverage	Mean Acceptability	Beverage	Mean Acceptability	Beverage	Mean Acceptability	Beverage	Mean Acceptability
Cherry	6.89^{a}	Lemon-Lime	6.94^{a}	Cherry	6.36^{a}	Cherry	6.00^{a}	Cherry	5.81^{a}
Grape	6.64^{ab}	Cherry	6.75^{a}	H_2O	6.17^{ab}	Lemon-Lime	5.92^{a}	Lemon-Lime	5.42^{ab}
Lemon-Lime	6.64^{ab}	Grape	6.56^{a}	Lemon-Lime	6.06^{abc}	Grape	5.83^{a}	Grape	5.33^{ab}
H_2O	6.03^{bc}	H_2O	6.53^{a}	Grape	5.58^{bcd}	Orange	4.92^{b}	Orange	4.81^{b}
Orange	5.94^{c}	Orange	5.58^{b}	Orange	5.42^{cd}	Tea	4.83^{b}	Tea	4.67^{b}
Tea	5.69^{c}	Tea	5.25^{b}	Tea	5.06^{d}	H_2O	4.81^{b}	H_2O	3.69^{c}

fashion. After cooking or preparation, samples were brought to one of five serving temperatures by immersion of the holding vessels in temperature-controlled water baths or refrigerators. The five temperatures were 40°, 55°, 70°, 100°, and 135°F (4.4°, 12.8°, 21.1°, 37.8° and 57.2°C) and covered a wide range of temperatures below, at and above ambient (70°F, 21.1°C) temperature.

Subjects were drawn from the same pool of volunteer employees as used in Experiment 1. Groups of 35 subjects each judged the acceptability of one of the 13 test foods at each of the five serving temperatures, using a 9-point hedonic scale. Samples were presented randomly to each subject and all samples were judged only once.

Results

Fig. 2 is a plot of the mean acceptability ratings as a function of serving temperature for the three beverages that were used in these tests. As was observed in Experiment 1, the data for the beverages that are normally served cold (lemonade and milk) show a monotonic decrease in acceptability with increasing serving temperature. However, the coffee, which is most commonly served hot, but is occasionally served cold (iced), shows a U-shaped function, with acceptability lowest at ambient temperature. ANOVA's carried out on the data showed significant effects ($p < 0.01$) of serving temperature on acceptability for all 3 beverages.

Fig. 3 shows plots of mean acceptability ratings as a function of serving temperature for the 10 solid or semi-solid foods. In each case, acceptability increases monotonically with serving temperature, reflecting a similar concordance of the maximum acceptability judgments with the temperature range at which the item is normally served. ANOVA's carried out on the data showed significant ($p < 0.01$) main effects of temperature for all foods tested.

Discussion

The results of Experiment 2 show that the effect of serving temperature on the acceptability of beverages and solid or semi-solid foods is a function of the temperature at which that beverage or food is normally served.

In the case of those beverages that are normally served cold (milk and lemonade) acceptability decreased monotonically with increasing temperature of the beverage (Fig. 2). In the case of coffee, which is served both hot and cold, acceptability was lowest at ambient temperature and increased at higher and at lower temperatures (Fig. 2). (This U-shaped function was not observed in the data for tea in Experiment 1 due to the use of an iced tea mix, the citric acid content of which gave it the sensory character of a "cold" drink.) For solid and semi-solid foods that are normally served hot, acceptability increased monotonically with increasing temperature (Fig. 3). Moreover, at ambient serving temperatures or below (40°, 55°, 70°F) the three food items with the highest acceptability ratings were apple pie, ham and biscuits (Fig. 3), all three of which are the most likely of the tested food items to be served at ambient temperatures or below.

Of further interest in the data presented in Fig. 2 and 3 is the fact that no beverage or food had maximum acceptability at ambient temperatures. This is true even for the three foods (apple pie, ham and biscuits) commonly served at these temperatures. It is likely that these data reflect the contribution of learned cultural factors in food acceptance, aided by product formulations designed to accomodate these cultural preferences. The population from which this subject sample was drawn consists of urban, middle class Americans residing in the Boston metropolitan area. Members of this population have become accustomed to eating foods and beverages that are stored and served at "ideal" temperatures. Whether similar preferences would be observed in poor rural areas or in underdeveloped countries, where heating and cooling accomodations for food may be minimal or absent is unknown. In addition, for formulated or processed foods and beverages, the cultural preferences for serving temperature are inherently incorporated into the formulation or processing of the product. A good example is iced tea mix or other cold beverages mixes. Since these products are normally served at low temperatures, relatively large percentages of sucrose, citric acid and flavoring are used in the formulation to compensate for the fact that gustatory and olfactory sensitivity is reduced at these temperatures. When served at high temperatures, these beverages are perceived as being extremely tart.

These data pose another interesting question, because several studies have shown maximal taste sensitivity and maximal taste intensity for model tastants when they are presented at ambient (72°F, 22°C) to body (98.6°F, 37°C) temperatures (Pangborn et al., 1970; McBurney et al., 1973). The fact that taste function should be maximal at ambient or body temperatures, but that these same temperatures should produce less than maximal acceptability for foods is perplexing. One adaptive mechanism that can be used to explain both the temperature/acceptability functions and the temperature-dependent sensitivity of the taste receptor system involves the effects on the organism of microbial contamination of ambient temperature foods. Through past experiences with such contaminated foods, a relative learned aversion to foods at ambient temperatures may develop within individual members of the species. Moreover, the survival value of a receptor system that is maximally sensitive to stimuli at ambient temperatures (for the purpose of detecting and signaling taste changes

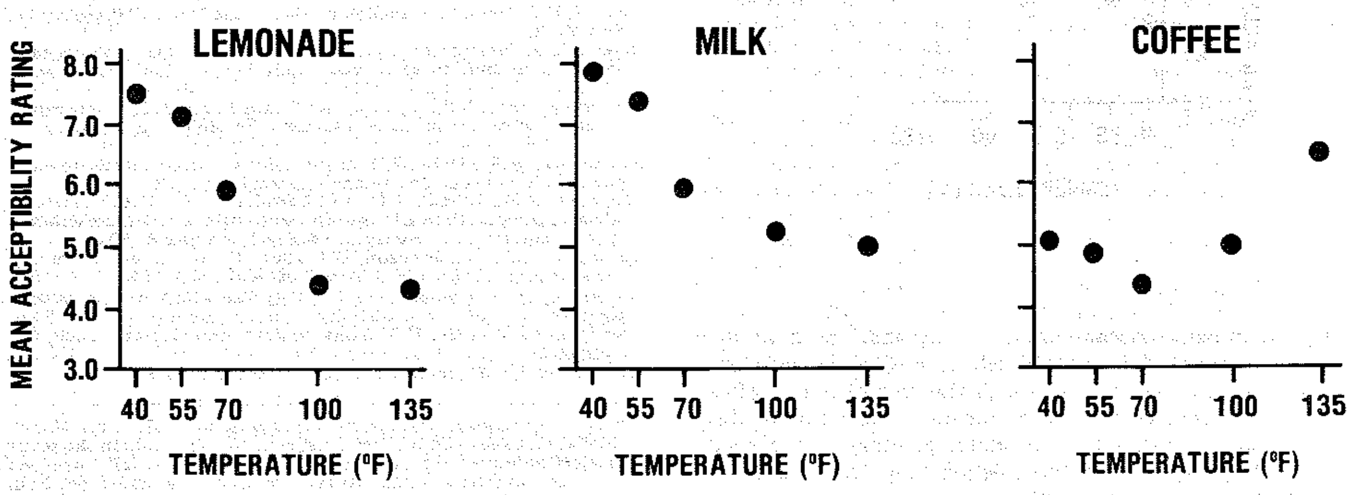
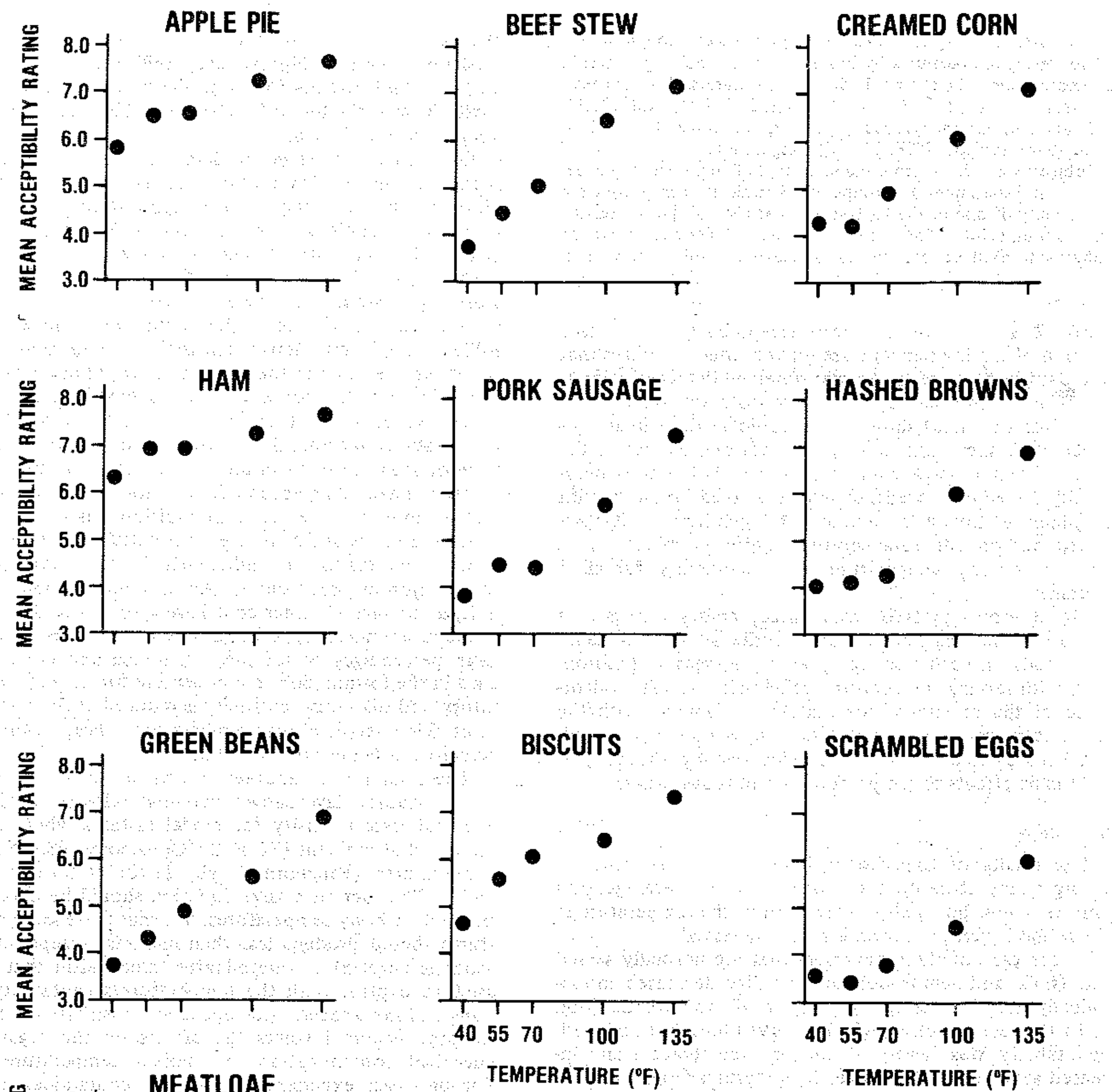


Fig. 2—Mean acceptability ratings as a function of serving temperature for the three beverages used in Experiment 2.



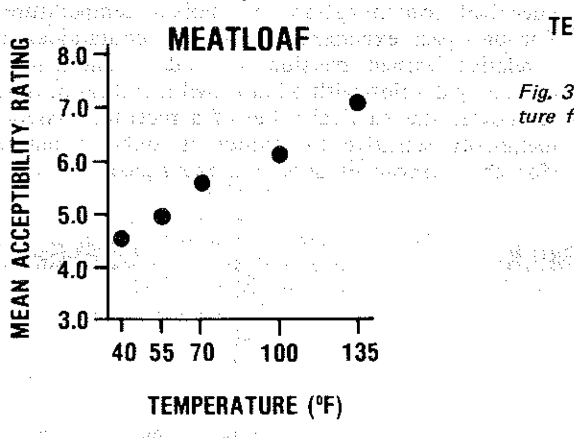


Fig. 3—Mean acceptability ratings as a function of serving temperature for the ten solid and semi-solid foods used in Experiment 2.

that accompany contamination or degradation of foods) may have resulted in natural selection of a temperature-dependent taste system. Although this hypothesis is plausible, the current lack of cross-cultural information in this area makes it difficult to evaluate, pointing to the need for further research on the role of food temperature in acceptance and consumption.

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